via e-mail

May 16, 2017
FPU17-197

Ms. Catherine Jerrard
AFCEC/CIBW
706 Hangar Road
Rome, NY 13441

RE: WAFB – ADEQ comments on Site ST012 contaminant mass estimation process. *LNAPL Volume Calcs;* received March 23, 2017. An Adobe.pdf of Amec Foster Wheeler (amec), assorted light non-aqueous phase liquid (LNAPL) volume calculations; from various time intervals between 2015 and 2017; received via amec email (Donald.Smallbeck@amecfw.com).

Dear Ms. Jerrard:

Arizona Department of Environmental Quality (ADEQ) Federal Projects Unit (FPU) appreciates the opportunity to submit comments regarding the Site ST012 contaminant mass estimation process. As the result of a regulatory agency-requested action item brought forth during a Williams Air Force Base (WAFB) Base Closure Team (BCT) discussion, *LNAPL Volume Calcs* information was received March 23, 2017 via an amec email (Donald.Smallbeck@amecfw.com). Praxis Environmental Technologies, Inc. reviewed amec-provided information and interpreted a contaminant mass which differs from amec's presented mass (BCT, *Site ST012 – EBR Applicability*, power point slides, page 12, March 16, 2017).

It is ADEQ's opinion that contaminant mass can impact a remedy efficacy and that underestimating the contaminant mass can negatively impact a selected remedy. ADEQ suggests amec re-assess the contaminant mass; re-evaluate remedy options, as appropriate; collect additional data, as needed; and complete remedy pilot studies, as applicable, to bolster the proper remedy's success potential.

The following information sources are associated by direct reference or inference:

- *Introduction;* ST012 contaminant mass calculation estimate package to support remedial action estimates and decisions; dated 3/17/17; originating amec foster wheeler, Portland, Maine (Job No. 91011100001, Phase 5200, Job Name Williams AFB, Site ST012). Base calculations up dated following the Phase 1 EBR investigation using data into August 2016. Additional characterization data from November and December 2016 to update mass extents.

- *Pre-SEE mass;* Estimating residual LNAPL volume remaining in the thermal treatment zone; dated 8/15/16; originating amec foster wheeler, Portland, Maine (Job No. 91011100001, Phase 5200, Job Name Williams AFB, Site ST012).

- *Post SEE mass;* Estimating residual LNAPL volume remaining at the site following SEE treatment; dated 9/28/15; originating amec foster wheeler, Portland, Maine (Job No. 91011100001, Phase 5200, Job Name Williams AFB, Site ST012).

- *Add. Char. Update;* Estimating the additional LNAPL volume remaining at the site following SEE treatment based on new information gathered from the Phase 2 site characterization investigation; dated 2/3/2017; originating amec foster wheeler, Portland, Maine (Job No. 91011100001, Phase 5200, Job Name Williams AFB, Site ST012).

- *TEA Estimate;* Estimate Stoichiometric Requirements for Terminal Electron Acceptors using LNAPL estimates to actual SEE results; dated 9/30/15; originating amec foster wheeler, Portland, Maine (Job No. 91011100001, Phase 5200, Job Name Williams AFB, Site ST012).

ADEQ's comments are presented below and on following pages.

General Comments

1. A wider range of initial mass estimates should be employed in calculations and extend as high as 1,655,000 gallons. This wider range is justified by the strong dependence of the mass estimates on total soil porosity as described in the specific comments. Previous measures of total soil porosity at the site yield an average of 0.4, significantly higher than the assumed value of 0.3.

2. Mistakes in the worksheets occur where estimated pre-SEE NAPL removal was subtracted from pre-SEE mass estimates calculated from TPH measurements. The mistake appears in the Worksheet "Pre-SEE mass" as described in the specific comments on this worksheet.

3. Calculation of remaining NAPL based on the subtraction of removed NAPL from initial NAPL is subject to the same variation as the initial estimate if post-SEE data are not collected from treated zones. Estimates of remaining NAPL should include field data collected post-SEE in the TTZ, TIZ and ROI. Assumed reductions of NAPL during SEE have no technical substantiation and appear to be arbitrary. The estimated total NAPL remaining post-SEE based on calculated saturations is 376,753 (95% reduction in TTZ) whereas the estimate based on literature saturations is 837,749 (70% reduction in TTZ). The difference in estimates is equal to the difference in estimates for the initial NAPL volume and valid justification is not provided for selecting one result over the other. Further, the persistence of NAPL appearance in former SEE process wells is not consistent with a 95% reduction in NAPL saturation.

4. Assumed reductions of benzene content in residual NAPL remaining post-SEE are not substantiated and appear to be arbitrary. The assumed reductions should not be employed to assess the mass of benzene remaining in post-SEE NAPL. The benzene mass in NAPL remaining in the TTZ, TIZ and ROI should be based on field data collected post-SEE including NAPL and groundwater analyses from the different treatment zones.

Specific Comments on the Worksheet entitled, "Pre-SEE mass"

1. As stated, "*A porosity of 0.3 for all lithologic units was used to maintain consistency with the TerraTherm design assumptions.*"

No data or other basis was provided for assuming a total porosity of 0.3. Field data presented in Appendix B of the TEE Pilot Test Work Plan (BEM, 2007) includes 10 soil samples collected for physical analyses from four borings at various depths ranging from 150 to 242 feet below ground surface. The range of measured porosity values was 0.27 to 0.50 with an average of 0.40 and a median of 0.42. Assuming a porosity of 0.4 (rather than 0.3) lowers the calculated NAPL mass estimates based on measures of TPH and increases the NAPL mass estimate based on literature values provided in Step 4 on sheet 3 of 5 in Worksheet "Pre-SEE mass". For a porosity of 0.4, the pre-SEE mass estimates are 689,500 gallons (down from 804,500 gallons) for the calculated saturations and 1,655,000 gallons (up from 1,241,000 gallons) for literature saturation values. These example calculations demonstrate the strong dependence of the NAPL mass estimate on porosity, bring into question the assumed value of 0.3, and indicate a wider range of initial mass estimates should be employed in subsequent calculations. The lower range is provided by a porosity of 0.3 and the upper by 0.4.

2. Key points include, "*Because LNAPL migration through the soil likely followed a tortuous path, an assumption of soil conditions being uniformly at residual saturation between known LNAPL-impacted locations may overestimate mass. To account for this potential an "uncertainty factor" was applied which provides a lower end estimate.*"

However, the LNAPL is also known to exist in pools within the saturated zone trapped beneath the interface of lesser permeable intervals overlying more permeable intervals (e.g., LPZ overlying the LSZ). Such pools are the likely source of persistent NAPL appearances in ST012-W11 and ST012-W37. An assumption of uniform residual saturation may underestimate this mass. To account for this potential an "uncertainty factor" should be applied which provides a higher end estimate and indicates a wider range of initial mass estimates should be employed in subsequent calculations

Additionally no technical or statistical basis was provided for assuming an "uncertainty factor" of 75% in the treatment volumes and 50% in EBR volumes.

The utilization of the "uncertainty factor" to lower the NAPL mass estimate was also illustrated to be unrealistic when compared to the NAPL mass removed during SEE as described in Step 7 of on page 6 of 7 in Worksheet "Post SEE mass".

3. Sheet 4 of 5 states, "*NAPL removal is only applied to volumes using literature residual saturation because calculated residuals already account for NAPL removal via the average TPH values.*"

The calculations on Sheet 5 of 5 show the estimate of NAPL mass based on measured TPH soil concentrations includes the subtraction of 10,067 gallons from the UWBZ and 24,620 gallons from the LSZ that occurred before the TPH measurements. The volume calculations should be corrected as these subtractions incorrectly reduce the treatment zone mass estimates by 5% in the UWBZ and 10% in the LSZ.

4. Sheet 5 of 5 Conclusion: "*Using the literature values that BEM used in previous site modeling during the TEE pilot test and the new interpretations of LNAPL extent, the volume of LNAPL in the thermal treatment* *zones is estimated to be between 545,000 and 725,000 gallons, leaving between 240,000 and 480,000 gallons in the area outside the thermal treatment zones.* "

For reasons cited above, the range should be based on a range for the porosity. Based on porosity, the volume of LNAPL in the thermal treatment zones is estimated to be between 760,000 and 1,000,000 gallons, leaving between 480,000 and 650,000 gallons in the area outside.

5. Sheet 5 of 5 Conclusion: "*Using the concentrations of TPH in the soil and the equation developed by Hawthorne and Kirkman, the amount of NAPL in the thermal treatment zone is estimated to be between 300,000 and 405,000 gallons, leaving between 185,000 and 365,000 gallons in the area outside the treatment zone.*"

For reasons cited above, the range should be based on a range for the porosity. Based on porosity variations, the volume of NAPL in the thermal treatment zone is estimated to be between 375,000 and 438,000 gallons, leaving between 314,000 and 367,000 gallons in the area outside the treatment zone.

Specific Comments on the Worksheet entitled, "Post-SEE mass"

6. Sheet 1 of 7 describes soil volumes with varying levels of NAPL removal during SEE in the CZ, UWBZ, LPZ, and LSZ. The soil volume in each vertical zone is divided areally into a TTZ (90%), surrounded by a TIZ (60%), that is surrounded by an ROI (30%) and finally remaining areas of no treatment by SEE.

The assumed reductions in each area and zone are arbitrary as no justification, case study, reference or other data were provided to support the assumptions. Therefore, these assumed reductions should not be employed to assess the mass remaining post-SEE. In particular, the assumption of a 30% reduction in NAPL mass in an unheated radius of influence (ROI) beyond the perimeter of extraction wells is inconsistent with site data and inconsistent with a Key Point in the Introduction Worksheet, "*Although some LNAPL was recovered prior to heating the subsurface, quantities were low and relatively unresponsive to water table depression caused by pumping initiated as part of the containment study.*" The assumption implies that 30% of the initial NAPL could have been recovered with pumping alone.

7. Sheet 1 of 7 describes the increase in temperature in the TTZ and TIZ as likely to cause a preferential volatilization of light VOCs including benzene. To account for this volatilization, volatilization reduction factors were applied to final mass estimates of NAPL in the TTZ (90%), the TIZ (25%), and elsewhere (0%).

The assumed volatilization reduction factors in each area are arbitrary as no operational data, case study, reference or other data were provided to support the assumptions. Therefore, these assumed reductions should not be employed to assess the mass of benzene remaining in post-SEE NAPL. Operational data from SEE may be available to assess a preferential removal of benzene compared to other NAPL components but an estimate for benzene mass removal based on extracted flow and measured benzene concentrations have not been provided. Is the 90% reduction in the TTZ based on distillation, and if so, was the mass of steam injected sufficient to effect this reduction? Is the 25% reduction in the TIZ based on dissolution, and if so, was the flow of water through this zone sufficient to effect this reduction?

8. Sheet 2 of 7 states, "*Contours were extended to include monitoring wells known to have observed LNAPL but lack additional evidence of LNAPL (e.g. boring logs not available).*"

The figures accompanying the mass estimate worksheets do not show any contours in the LSZ extending out to LSZ-43 in contradiction to this statement. As a result, the volume of NAPL-impacted soil and NAPL volume that was untreated by SEE are underestimated.

9. Step 6 on Sheet 4 of 7 includes a table with estimates of post-SEE residual NAPL.

No explanation was provided describing how the "Untreated EBR Volume" was calculated. The reported volumes suggest the volumes were simply the estimate of the initial volumes from Worksheet "Pre-SEE mass" less the revised estimated volumes of NAPL in the TTZ, TIZ and ROI presented in Step 4. If correct, do the estimates for the UWBZ and LSZ in the final column of Literature volume include the estimated NAPL in the "Mass Extent Attributed to Additional Characterization" shown in the accompanying figures? If this additional mass is not included, the Literature Volume (last column) in the LSZ for Untreated EBR should be about 500 gallons instead of 49,738 gallons.

The estimate for the remaining NAPL in the TTZ of the UWBZ using calculated saturations (first column) is 13,180 gallons incorrectly including NAPL removed before TPH measurements were made. The correct estimate appears to be 15,614 gallons.

The two groups of rows entitled, "Cobble Zone and Upper Water Bearing Zone Thermal Treatment Zone" and "Lower Saturated Zone Thermal Treatment Zone" have no explanation for how they were calculated or how they are used.

10. Step 7 on Sheet 6 of 7 provides a comparison of NAPL volume removed during SEE to calculated NAPL removal using assumed reduction factors and estimated initial NAPL volumes.

Model validity based on a "best fit" of calculated mass removed using an assumed reduction factor compared to the measured mass removed is flawed; the logic is circular. For example, using the literature calculated NAPL volume in the TTZ of the LSZ of 360,727 gallons and a reduction factor of 33% yields exactly the same NAPL removed as the TPH calculated NAPL volume with a reduction factor of 90%. Without substantiation, no valid reason exists to select one reduction factor over the other based on mass removed.

For the reason described above, the mass remaining in the TTZ, TIZ and ROI should be based on field data collected after completing SEE rather than unsubstantiated assumptions. The appearance and recovery of NAPL in former SEE process wells, including former steam injection wells, does not support a 90% reduction in NAPL volume if the initial, unheated NAPL volume was primarily residual. The volume of NAPL remaining in the TTZ, TIZ and ROI cannot be estimated with validity without the collection additional field data (soil sampling, groundwater sampling, etc.) consistent with the data collected to assess the initial NAPL volume.

11. Step 7 on Sheet 7 of 7 provides calculations of benzene mass in the remaining NAPL based on a uniform mass fraction of benzene in the pre-SEE NAPL and assumed reduction factors in benzene mass fraction in various treatment zones.

The assumed mass fraction of benzene in the pre-SEE NAPL appears to be uniform at 0.00356 although no value is provided in the Worksheet. A footnote states the value is based on LNAPL analysis during SEE, not before. Previous investigations at ST012 have analyzed NAPL samples for its makeup. These results are provided in Appendix L of the TEE Pilot Test Evaluation Report (2011) where the benzene mass fraction for modeling was reported to be 0.00222 in the UWBZ and 0.0083 in the LSZ. The UWBZ was unsaturated at the time of NAPL release and the residual NAPL in the UWBZ was weathered by natural volatilization and soil vapor extraction before becoming submerged. The result is a lower mass fraction of volatile compounds than found in the deeper LSZ NAPL that was weathered primarily by dissolution, a slower process. The benzene mass fractions cited in BEM (2011) for the separate zones is recommended over the single value of 0.00356.

As described in the comment above, the assumed volatilization reduction factors in each area are arbitrary as presented and should not be employed to assess the mass of benzene remaining in post-SEE NAPL. The benzene mass in NAPL remaining in the TTZ, TIZ and ROI should be based on field data collected post-SEE including NAPL and groundwater analyses from the different treatment zones.

Calculated benzene mass can be checked for consistency by comparison to GW concentrations. For the assumed mass fraction of 0.003556 in JP-4, the mole fraction of benzene is approximately 0.005 yielding an equilibrium groundwater concentration of 9 mg/L with the pre-SEE NAPL. A 90% reduction of mass fraction lowers the equilibrium groundwater concentration to about 0.9 mg/L. Hence, benzene concentrations in the former TTZ should not exceed 1 mg/L based on the Worksheet assumptions. These results also illustrate that a NAPL equilibrium concentration in groundwater will not approach MCL until the mass fraction is reduced by an additional two orders of magnitude.

12. The Conclusion states, "*Contaminant mass remaining after SEE implementation was calculated. This method uses the final mass removed, as reported during TerraTherm weekly reports, to determine an adjusted percent removal by zone. Using the adjusted percent removal by zone, the remaining BTEX+N at the site is estimated to be between 134,000 and 194,000 pounds with a worst case scenario of up the 290,000 pounds.*"

As described in the comments above, these calculated masses of remaining BTEX+N are based on unsubstantiated assumptions for reduction. As demonstrated in the example calculation for the LSZ, any calculation of remaining NAPL based on the subtraction of NAPL removed from (widely varying estimates of) initial NAPL is subject to the same wide variation as the initial estimate. The most reliable method of assessing mass removed is the assessment of field data collected post-SEE.

Closure

ADEQ may add or amend ADEQ comments if evidence to the contrary of our understanding is discovered; if received information is determined to be inaccurate; if any condition was unknown to ADEQ at the time this document was submitted or electronically delivered; if other parties bring valid and proven concerns to our attention; or site conditions are deemed not protective of human health and the environment within the scope of this Department.

Thank you for the opportunity to comment. Should you have any questions regarding this correspondence, please contact me by phone at (602) 771-4121 or e-mail miller.wayne@azdeq.gov.

Sincerely,
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